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(54) **HEAT EXCHANGER WITH ANNULAR INLET/OUTLET FITTING**

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CPC ***F28F 1/00*** (2013.01); ***F28D 9/005*** (2013.01); ***F28D 9/0037*** (2013.01); ***F28F 3/12*** (2013.01); ***F28F 9/0253*** (2013.01)

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See application file for complete search history.

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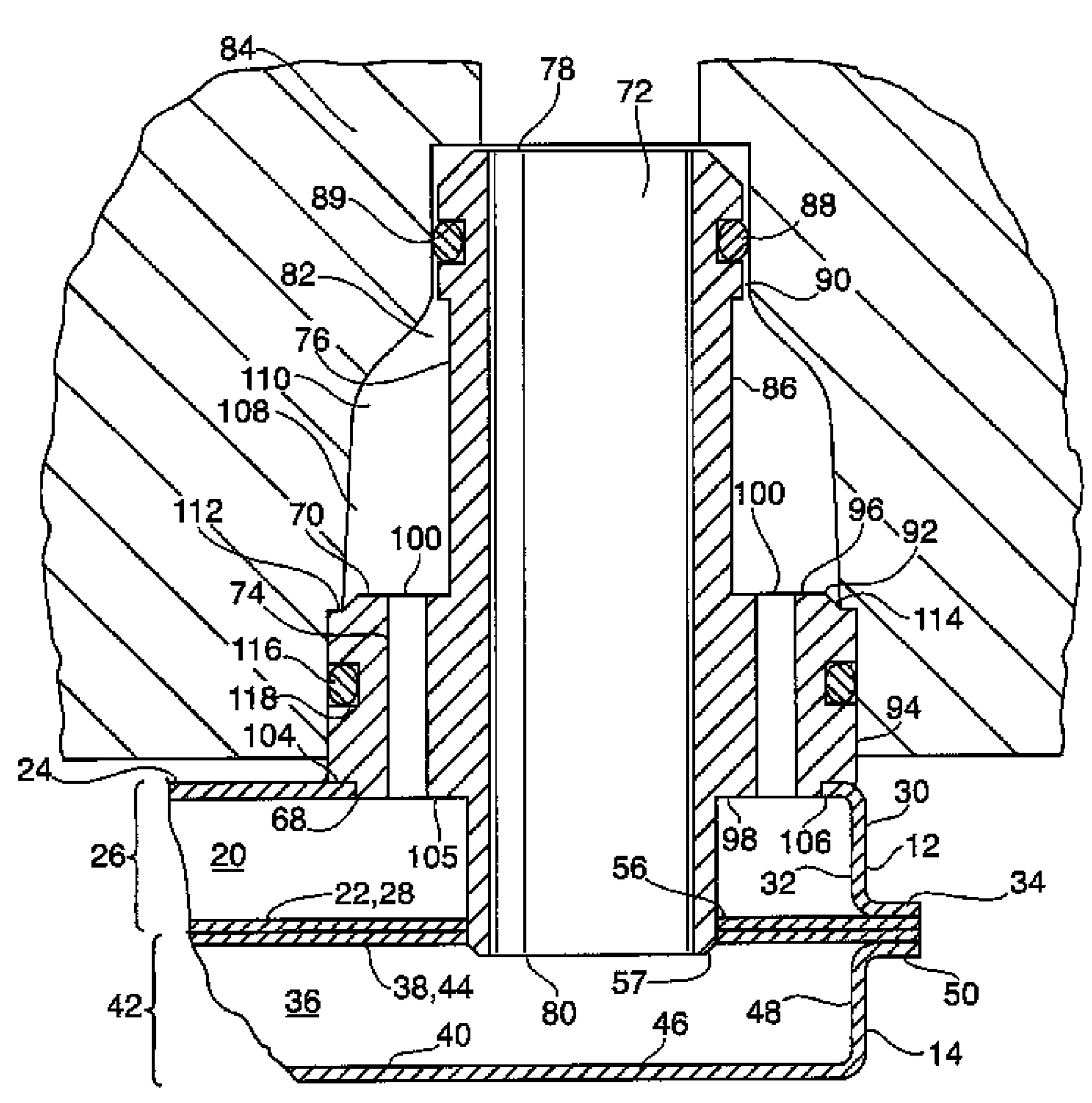
(57) **ABSTRACT**

A heat exchanger has first and second flow passages with a communication passage therebetween. An inlet/outlet opening in a wall of the first passage receives a one-piece inlet/outlet fitting having an inner tube and an outer ring connected by webs, the tube and ring defining inner and outer flow passages in direct flow communication with the first and second flow passages, respectively. A first end of the tube and an outer surface of the ring are provided with resilient sealing members for sealing within a bore of a coolant manifold. The ring has a planar sealing surface which is sealed to the wall of the first passage, and the second end of the inner tube extends through the first fluid flow passage and is sealed inside the communication passage. Lateral adjustment of the fitting within the inlet/outlet opening compensates for stack-up tolerance variation in the heat exchanger.

16 Claims, 8 Drawing Sheets



(51) **Int. Cl.**
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F28D 9/00 (2006.01)

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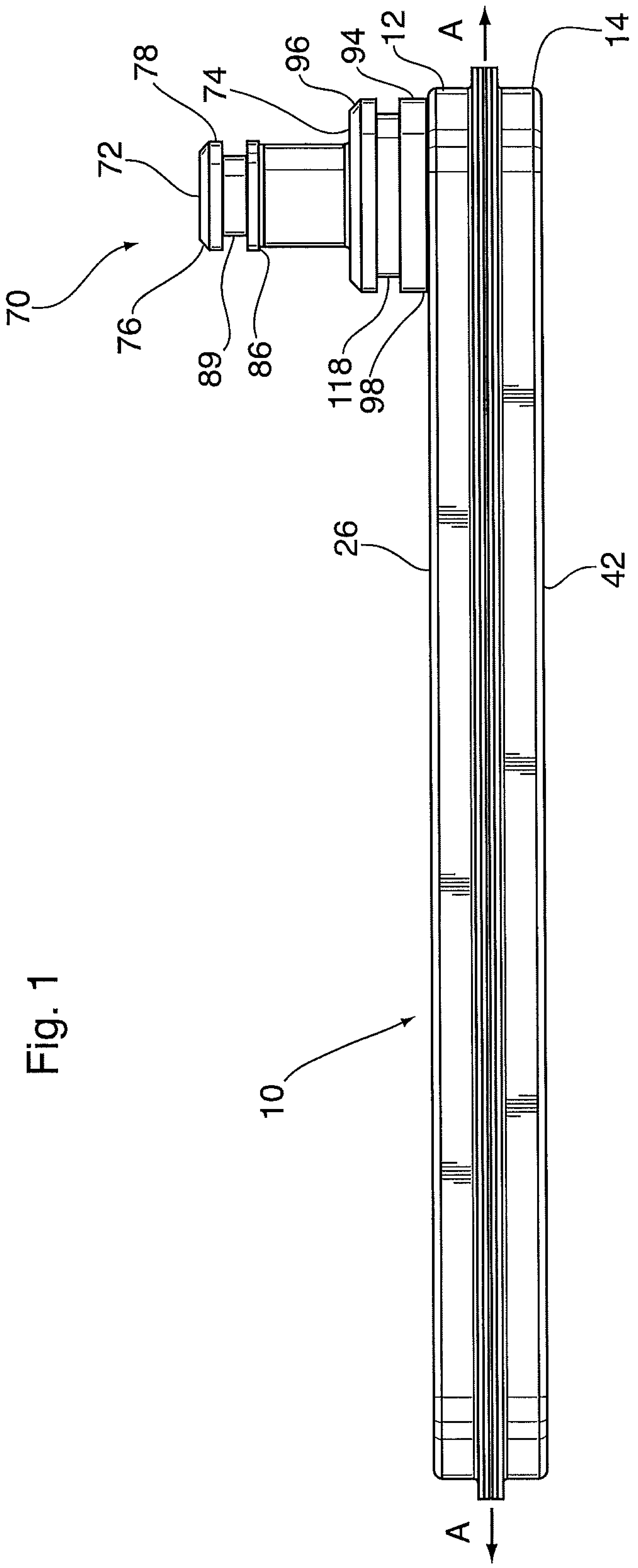

Fig. 1

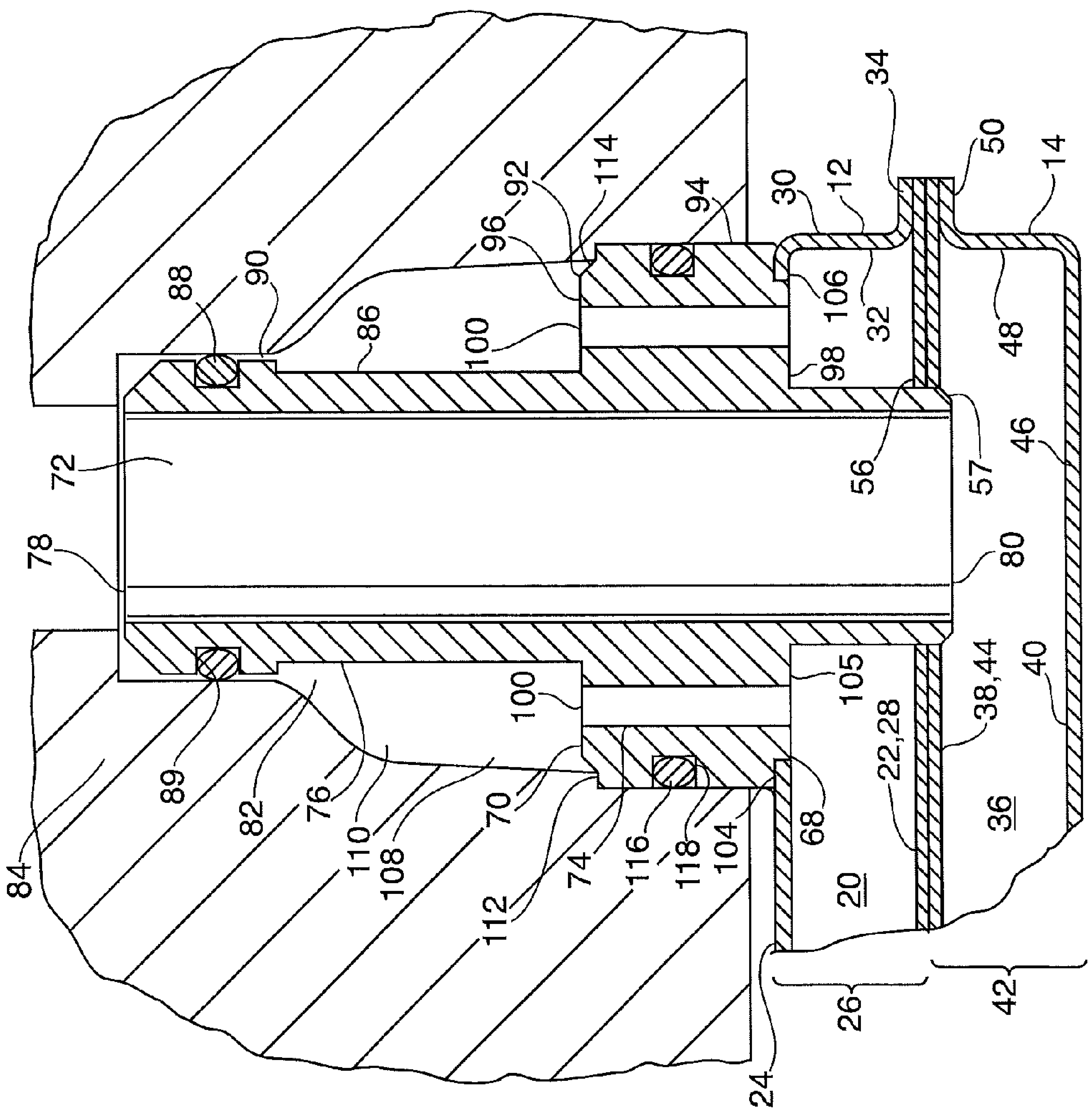

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Fig. 2

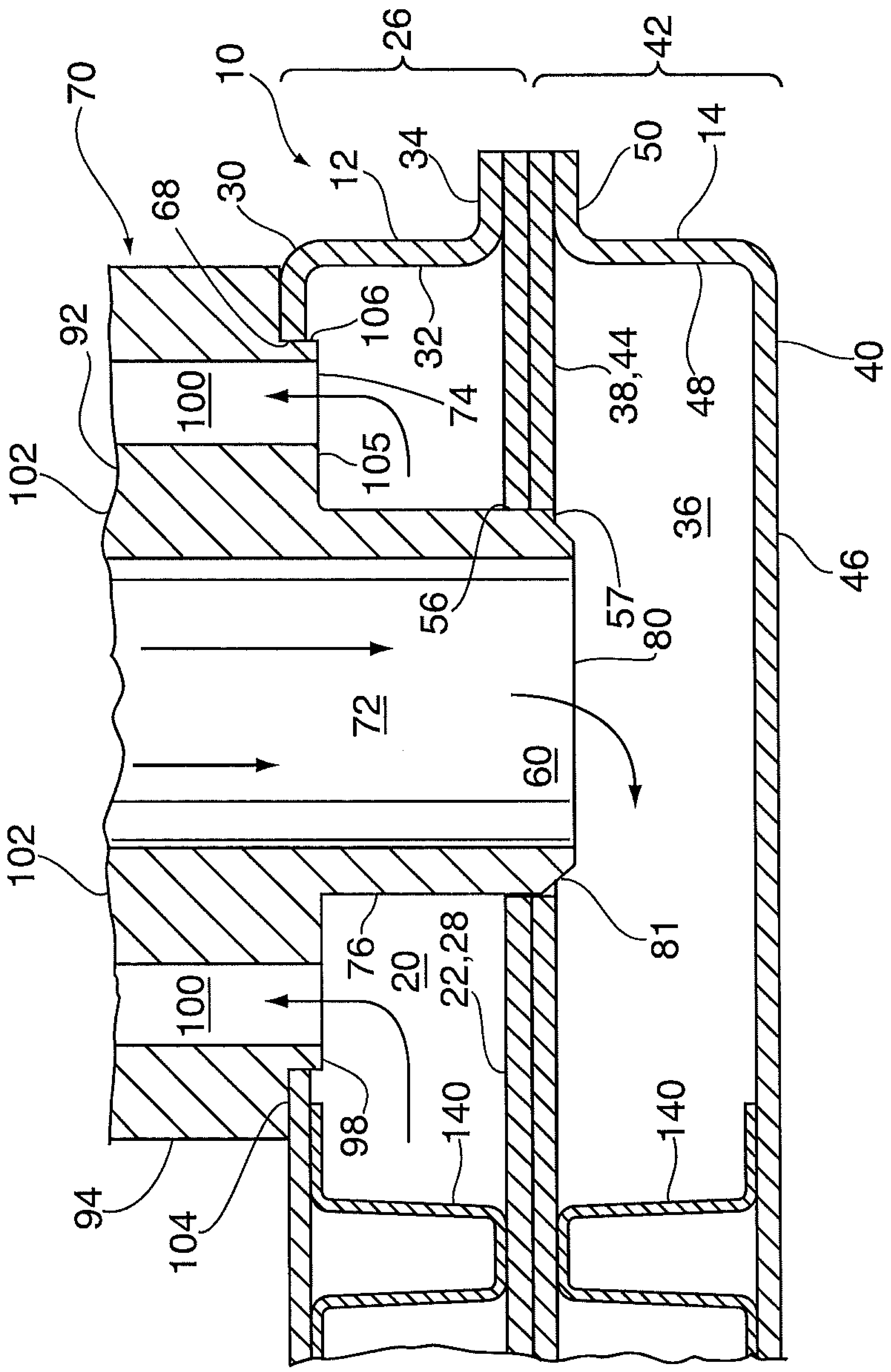
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Fig. 3

Fig. 3A

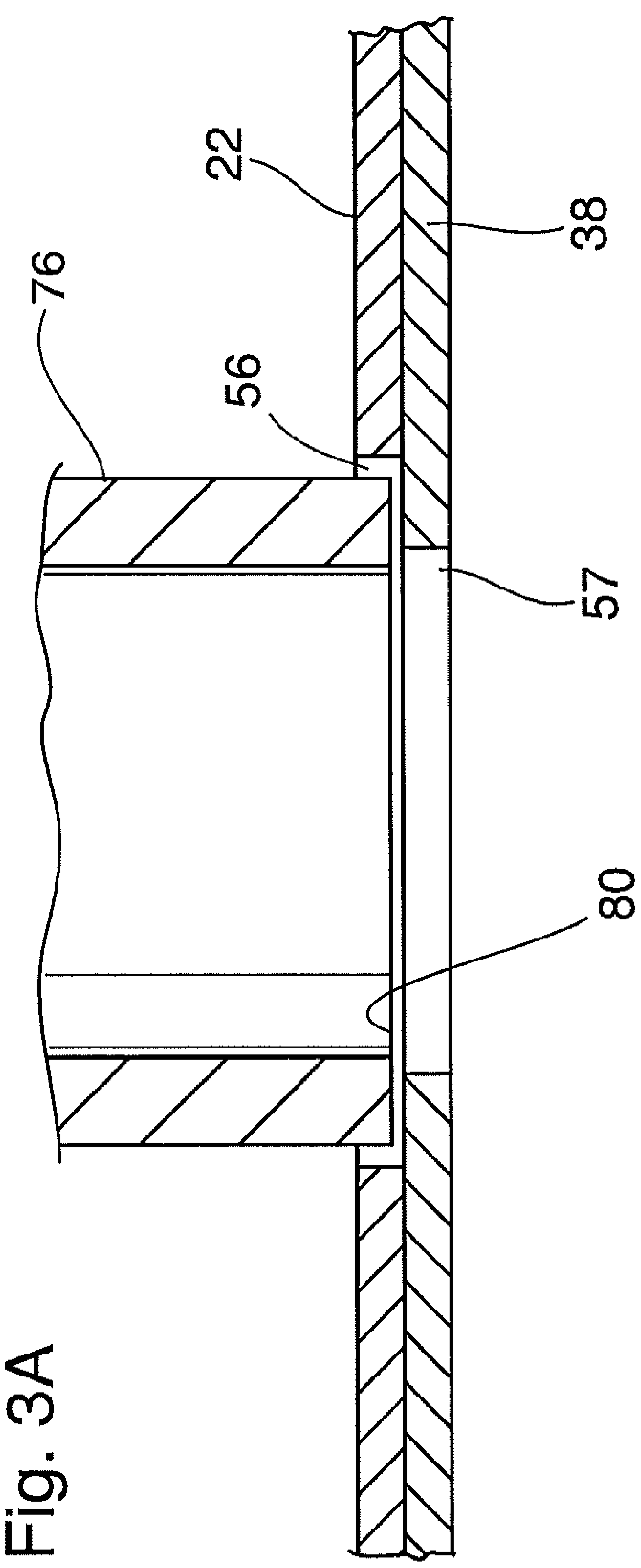
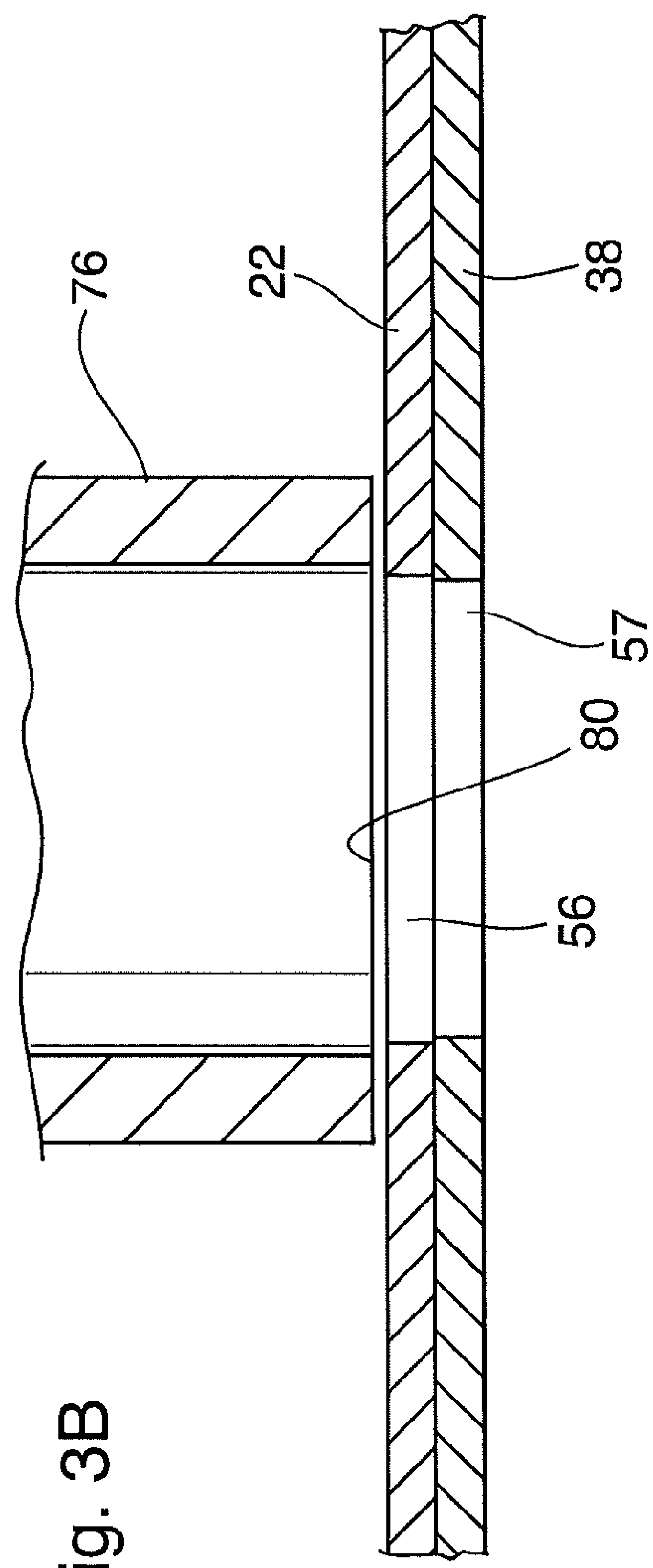


Fig. 3B



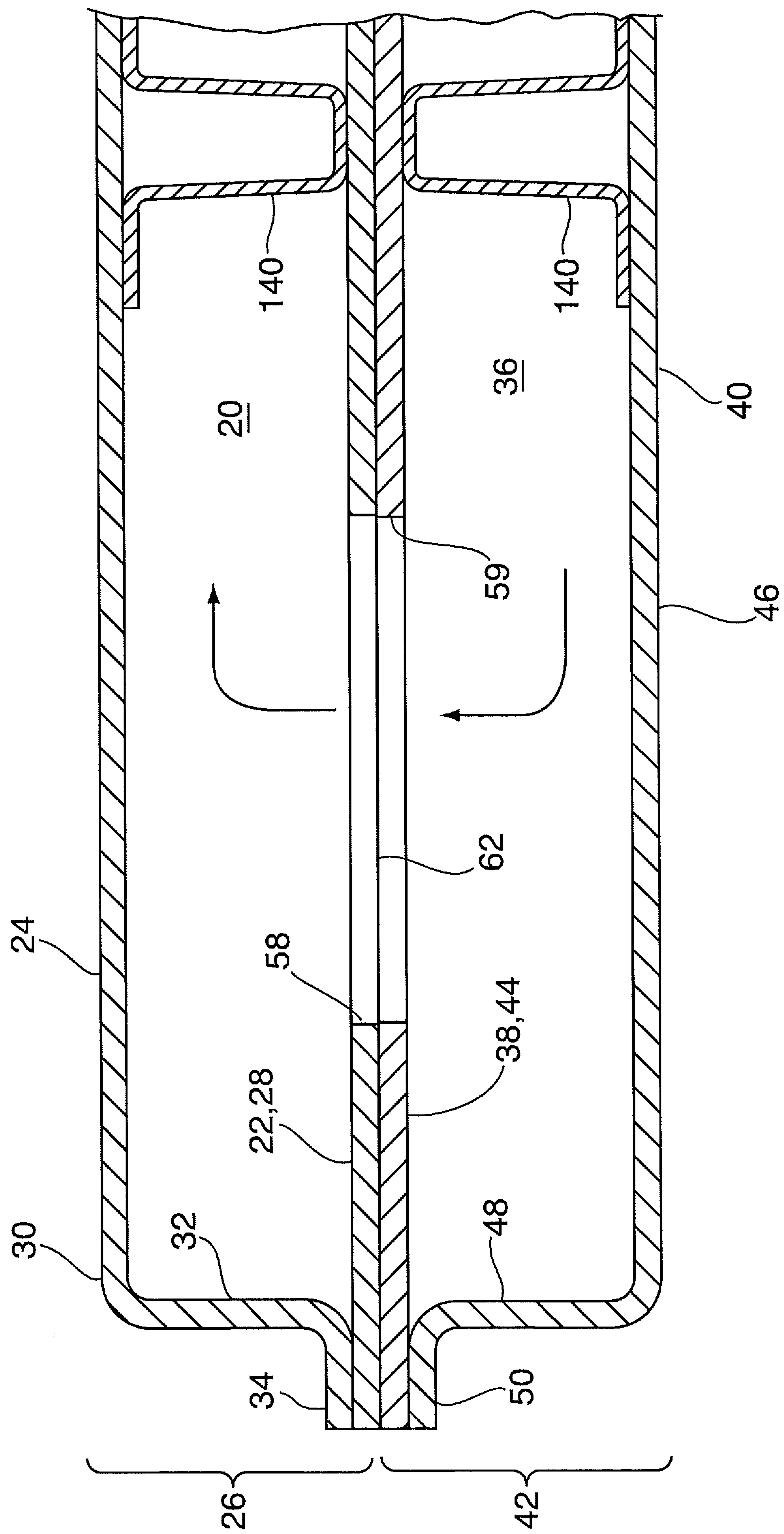


Fig. 4

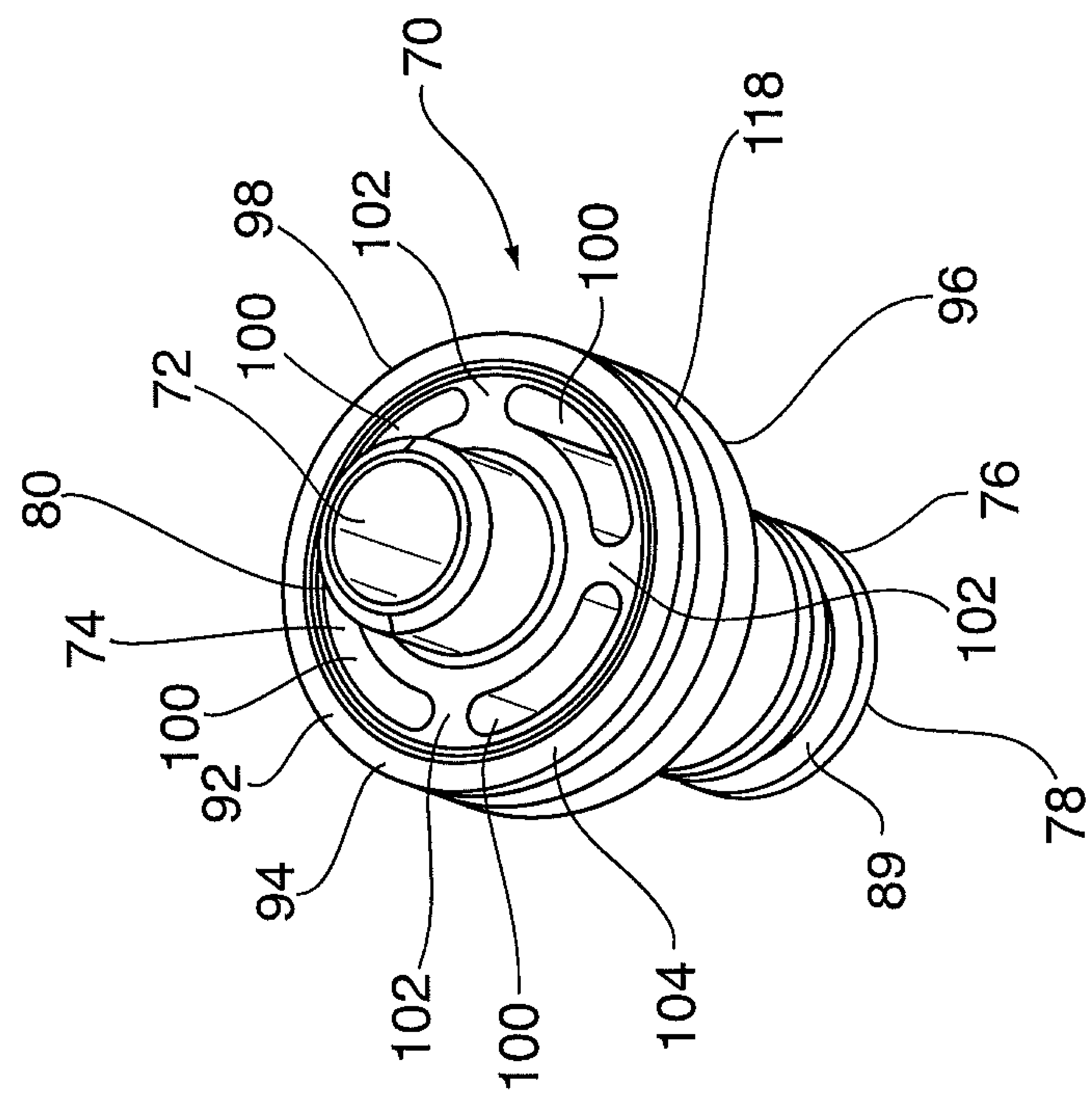

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Fig. 6

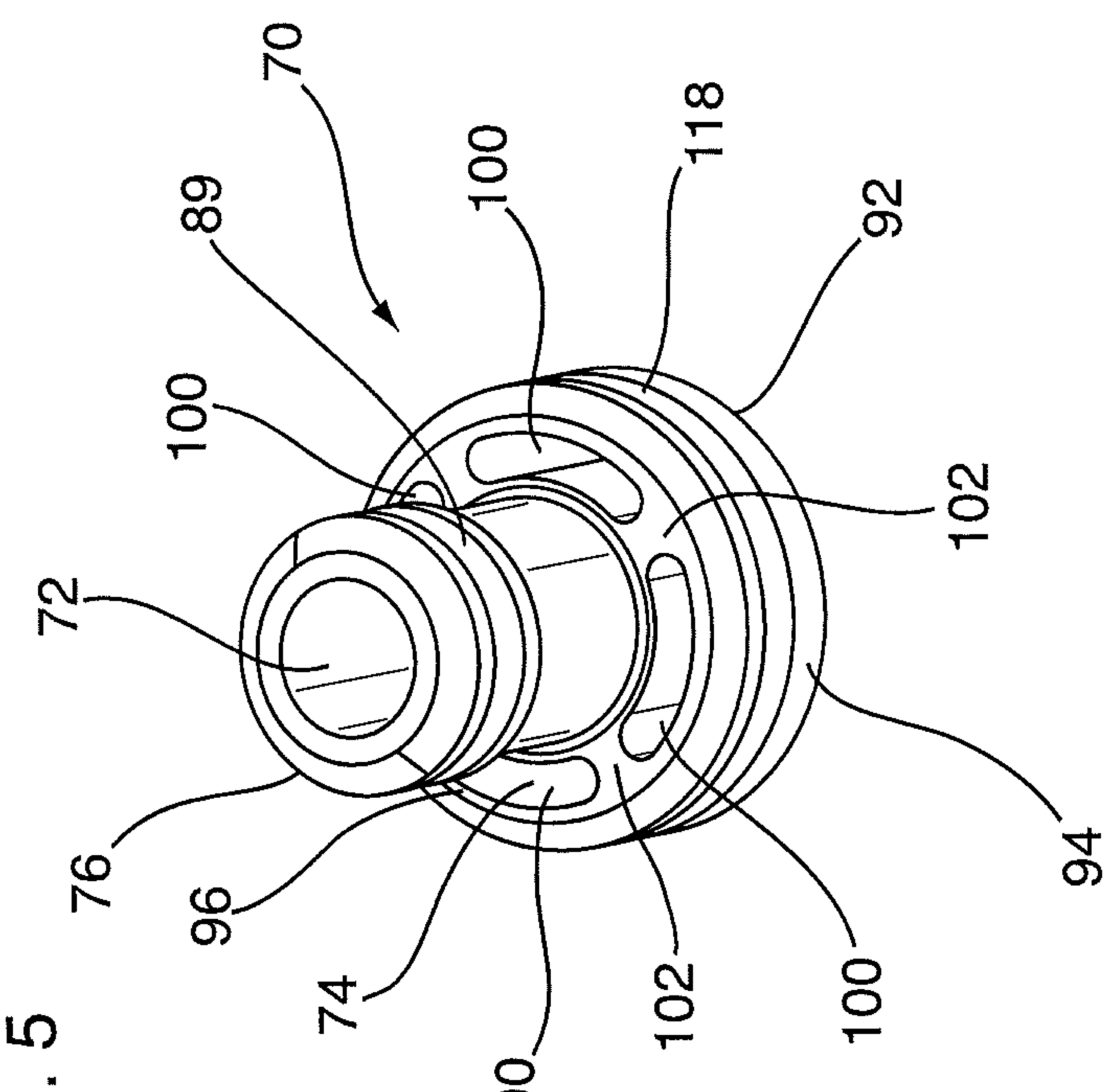
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Fig. 5

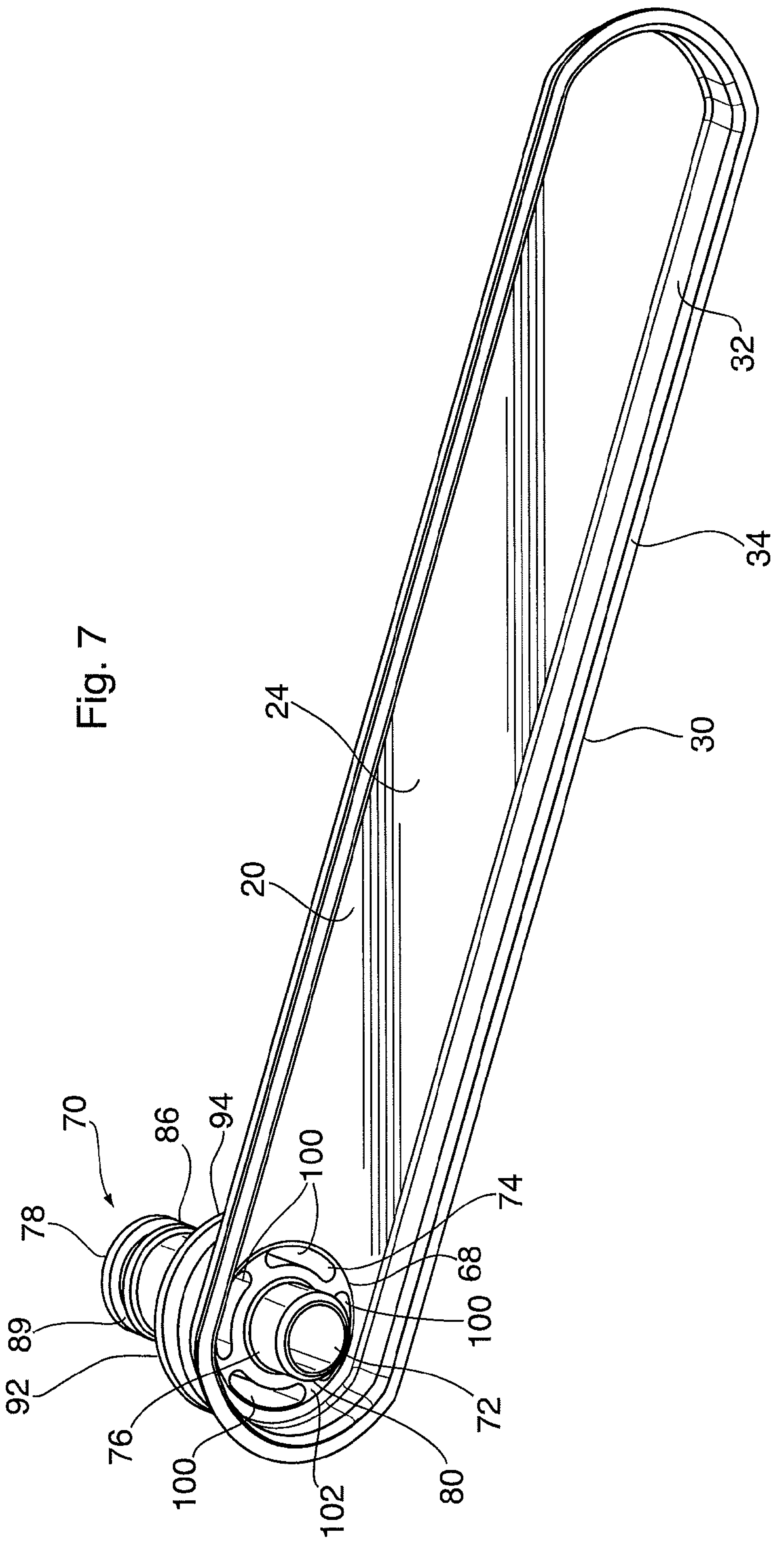
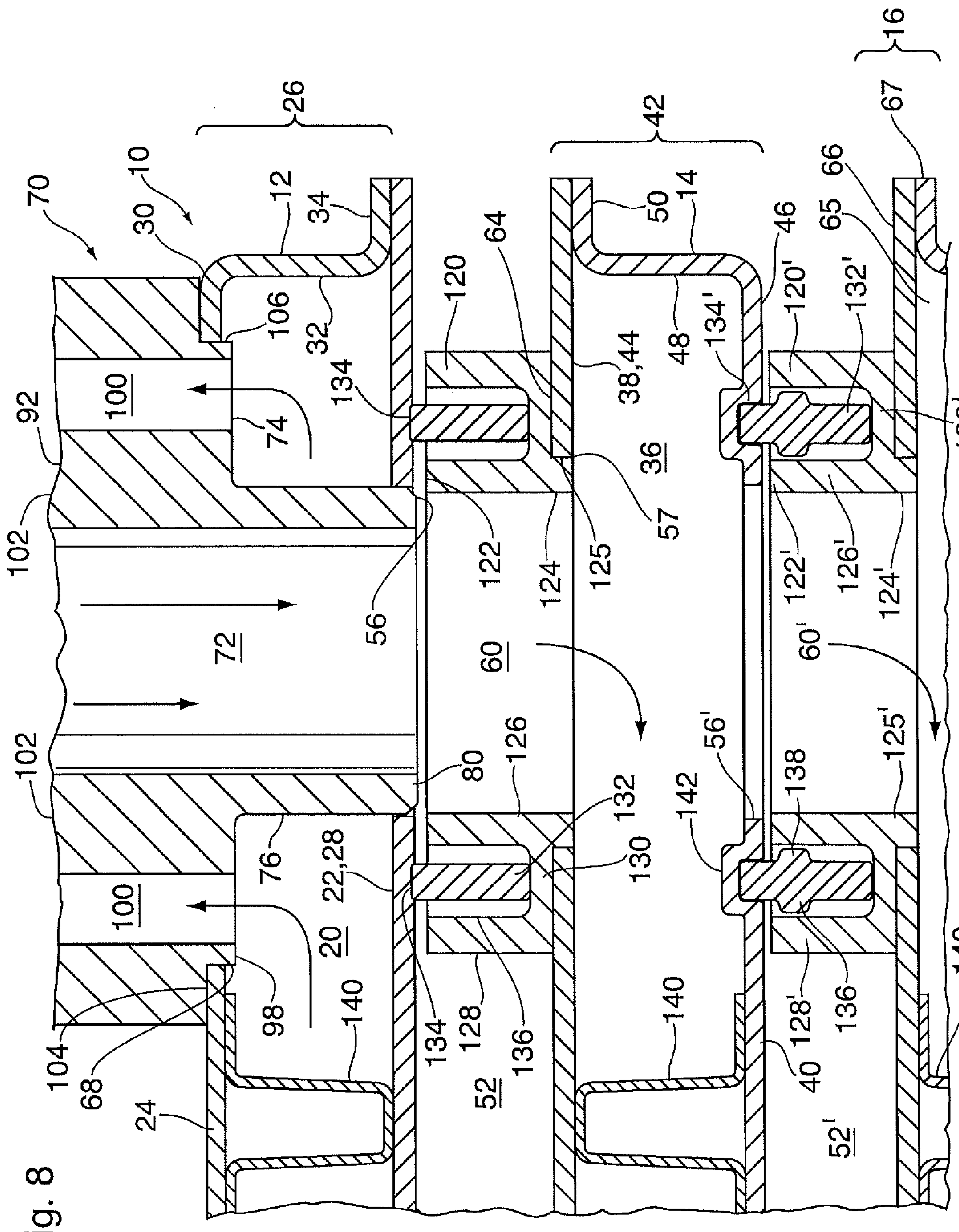


Fig. 7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128'
52'
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Fig. 8

HEAT EXCHANGER WITH ANNULAR INLET/OUTLET FITTING

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority to and the benefit of U.S. Provisional Patent Application No. 61/762,412 filed Feb. 8, 2013, the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates to a heat exchanger with a combined inlet/outlet fitting having integral construction and providing enhanced sealing and alignment.

BACKGROUND

In the manufacture of heat exchangers, parts must be assembled with a high degree of precision to ensure reliable sealing and performance. In certain heat exchanger configurations assembly within required tolerances can be challenging, making it difficult to achieve reliable and accurate sealing and alignment of the two portions of the heat exchanger.

SUMMARY

According to an embodiment, there is provided a heat exchanger comprising: at least a first enclosed fluid flow passage and a second enclosed fluid flow passage, wherein each of the fluid flow passages is defined between a first wall and a second wall; first and second communication openings provided in the first wall of each of the first and second flow passages, wherein the first communication opening of the first flow passage aligns with the first communication opening of the second flow passage and the second communication opening of the first flow passage aligns with the second communication opening of the second flow passage; an inlet/outlet opening provided in the second wall of the first flow passage, wherein the inlet/outlet opening is aligned with the first communication opening in the first wall of the first flow passage; an inlet/outlet fitting received in the inlet/outlet opening, wherein the inlet/outlet fitting has an inner tubular passage surrounded by an outer annular passage, wherein the inner tubular passage is defined by an inner cylindrical tube having a first end and a second end, wherein the inlet/outlet fitting further comprises an outer annular ring having a first end and a second end, wherein the outer annular ring surrounds the inner cylindrical tube and is connected thereto, and wherein the outer annular passage is defined between the inner cylindrical tube and the outer annular ring; wherein the second end of the outer annular ring has a planar sealing surface surrounding the outer annular passage, and wherein the planar sealing surface of the outer annular ring is sealingly connected to an area of the second wall of the first flow passage surrounding the inlet/outlet opening, such that the first flow passage is in fluid flow communication with the outer annular passage of the inlet/outlet fitting; and wherein the second end of the inner cylindrical tube extends through the first flow passage and is in sealed fluid flow communication with the second flow passage, such that the second flow passage is in fluid flow communication with the inner tubular passage of the inlet/outlet fitting.

According to an embodiment, the first and second flow passages are defined by respective first and second plate pairs, each of the plate pairs comprising a pair of plates sealed together at their edges, and wherein the first plate includes the first wall and the second plate includes the second wall, and wherein the inlet/outlet opening is substantially concentrically aligned with the first communication openings in each of the first and second flow passages.

According to an embodiment, the first end of the inner cylindrical tube extends beyond the first end of the outer annular ring and has an outer surface provided with a resilient sealing member for sealing the first end of the inner cylindrical tube within a first inner bore of a fluid opening; and the outer annular ring has a cylindrical outer surface provided with a resilient sealing member for sealing the cylindrical outer surface of the annular ring within a second inner bore of said fluid opening, wherein the first inner bore and the second inner bore are concentric with one another. For example, the resilient sealing member of the outer annular ring and the resilient sealing member of the inner cylindrical tube may each comprise an O-ring.

According to an embodiment, the outer annular ring is integrally formed with the inner cylindrical tube, and the outer annular ring is rigidly connected to the inner cylindrical tube through a plurality of webs, such that the outer annular ring is concentric with the inner cylindrical tube.

According to an embodiment, the planar sealing surface of the outer annular ring has an annular shape, with an outer peripheral edge and an inner peripheral edge. Also, a diameter of the planar sealing surface at the outer peripheral edge may be greater than a diameter of the inlet/outlet opening, and a diameter of the planar sealing surface at the inner peripheral edge may be less than the diameter of the inlet/outlet opening. For example, the second end of the outer annular ring may comprise a shoulder located at the inner peripheral edge of the planar sealing surface and outwardly from the outer annular passage, wherein the shoulder has a diameter which is smaller than the diameter of the inlet/outlet opening, and is received inside the inlet/outlet opening. The diameter of the shoulder may differ from the diameter of the inlet/outlet opening by an amount which is at least as great as a stack-up tolerance variation of the heat exchanger.

According to an embodiment, the second end of the inner cylindrical tube has an outer cylindrical surface having a diameter which is less than a diameter of the first communication opening in the first wall of the first flow passage, and wherein the outer cylindrical surface of the tube is sealed to the first wall of the first flow passage. For example, the outer cylindrical surface of the inner cylindrical tube may be sealed to an inner peripheral surface of the first communication opening of the first flow passage, and/or may be sealed to the first wall of the first flow passage by brazing or welding.

According to an embodiment, the first wall of the first flow passage is in engagement with the first wall of the second flow passage, and wherein the first communication openings of the first and second flow passages are in substantial concentric alignment with one another. For example, the second end of the inner cylindrical tube may extend at least partially through the first communication opening in the first wall of the second flow passage, and/or the second end of the inner cylindrical tube may be sealed to the first wall of the second flow passage within the first communication opening of the second flow passage.

According to an embodiment, a space is provided between the first wall of the first flow passage and the first wall of the second flow passage, and a spacer may be provided in the space between the first wall of the first flow passage and the first wall of the second flow passage. The spacer may comprise: a hollow interior; a first end forming a sealed connection with the first wall of the first flow passage in an area surrounding the first communication opening of the first flow passage; and a second end forming a sealed connection with the first wall of the second flow passage in an area surrounding the first communication opening of the second flow passage. The spacer may comprise an annular ring having an inner cylindrical side wall, an outer cylindrical side wall spaced from the inner cylindrical side wall, and a bridging portion extending between and connecting the side walls together, wherein the inner cylindrical side wall, the outer cylindrical side wall and the bridging portion together define the hollow interior of the spacer. The cylindrical side walls and the bridging portion of the spacer may have a U-shaped appearance in cross-section, and wherein the second end of the spacer includes a shoulder which is received inside the first communication opening in the first wall of the second fluid flow passage. The spacer further comprises a resilient sealing member in the form of a sealing ring received inside the hollow interior. The first wall of the first flow passage may have an annular groove surrounding the first communication opening formed therein, and wherein the resilient sealing member has a first end received inside the annular groove and a second end received inside the hollow interior of the spacer, in engagement with the bridging portion.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. **1** is a side elevation view of a heat exchanger according to a first embodiment of the invention;

FIG. **2** is an enlarged, partial cross-section along the central longitudinal axis of the heat exchanger of FIG. **1**, showing the fitting end of the heat exchanger;

FIG. **3** is a further enlarged longitudinal cross-section similar to FIG. **2**;

FIGS. **3**A and **3**B are enlarged, partial cross-sections showing alternate sealing arrangements at the second end of the inner cylindrical tube of the inlet/outlet fitting;

FIG. **4** is an enlarged, partial cross-section along the central longitudinal axis of the heat exchanger of FIG. **1**, showing the end of the heat exchanger remote from the fitting;

FIGS. **5** and **6** are respective front and rear perspective views showing an annular inlet/outlet fitting according to the invention in isolation;

FIG. **7** is a bottom perspective view showing the annular inlet/outlet fitting and a heat exchanger plate according to the invention; and

FIG. **8** is an enlarged, partial cross-section along the central longitudinal axis of a heat exchanger according to a second embodiment, showing the fitting end of the heat exchanger.

DETAILED DESCRIPTION

A heat exchanger **10** according to a first embodiment of the invention is described below with reference to FIGS. **1** to **7**.

Heat exchanger **10** comprises a first portion **12** (the upper portion in FIG. **1**) and a second portion **14** (the lower portion in FIG. **1**). The first portion **12** of heat exchanger **10** defines a first enclosed fluid flow passage **20** (referred to herein as the "first flow passage"), wherein the first flow passage **20** is defined between a first wall **22** and a second wall **24**. In the construction shown in the drawings, the first flow passage **20** is defined by a first plate pair **26** comprising a pair of plates **28**, **30** sealed together at their peripheral edges, and wherein the first plate **28** includes the first wall **22** and the second plate **30** includes the second wall **24**. In the first embodiment, the first wall **22** and the first plate **28** are flat and planar. The second plate **30** is shaped, with the second wall **24** forming a flat, planar plate bottom of the second plate **30**, the second wall **24** being surrounded by a raised peripheral flange **32** having a peripheral sealing surface **34** along which the second plate **30** is sealingly joined to the first plate **28**, for example by brazing or welding.

The second portion **14** of heat exchanger **10** similarly defines a second enclosed fluid flow passage **36** (referred to herein as the "second flow passage"), wherein the second flow passage **36** is defined between a first wall **38** and a second wall **40**. In the construction shown in the drawings, the second flow passage **36** is defined by a second plate pair **42** comprising a pair of plates **44**, **46** sealed together at their peripheral edges, and wherein the first plate **44** includes the first wall **38** and the second plate **46** includes the second wall **40**. In the first embodiment, the first wall **38** and the first plate **44** are flat and planar. The second plate **46** is shaped, with the second wall **40** forming a flat, planar plate bottom of the second plate **46**, the second wall **40** being surrounded by a raised peripheral flange **48** having a peripheral sealing surface **50** along which the second plate **46** is sealingly joined to the first plate **44**, for example by brazing or welding.

As shown in the drawings, the first walls **22**, **38** may be parallel to the respective second walls **24**, **40**, and the first and second flow passages **20**, **36** may also be parallel to one another. In addition, it can be seen from the drawings that the heat exchanger **10** has a central longitudinal axis A which is parallel to a long dimension of the plate pairs **26**, **42** and to the directions of fluid flow through the first and second flow passages **20**, **36**. The plate pairs **26**, **42** are elongate and the flow passages **20**, **36** extend from one end of the plate pairs **26**, **42** to the other end thereof. Although not essential to the invention, the heat exchanger plates **28**, **30**, **44**, **46** may be comprised of aluminum or an aluminum alloy.

The first walls **22**, **38** of the first and second flow passages **20**, **36** are each provided with first and second communication openings. In this regard, the first and second communication openings of first wall **22** are labelled as **56** and **58**, respectively, while the first and second communication openings of first wall **38** are labelled as **57** and **59**, respectively. In this embodiment of the invention, the communication openings **56**, **58** are located proximate to opposite ends of first wall **22**, and the communication openings **57**, **59** are located proximate to opposite ends of first wall **38**. As shown in FIGS. **2** and **3**, the first communication opening **56** provided in the first wall **22** of the first flow passage **20** aligns with the first communication opening **57** provided in the first wall **38** of the second flow passage **36**, thereby forming a first communication passage **60** proximate to the fitting end of the heat exchanger **10**. Also, as shown in FIG. **4**, the second communication opening **58** in the first wall **22** of the first flow passage **20** aligns with the second communication opening **59** in the first wall **38** of the second flow passage **36**, thereby forming a second communication passage **62** proximate to the end of the heat exchanger **10** which does not have a fitting.

An inlet/outlet opening **68** through which the liquid coolant enters and leaves the heat exchanger **10** is provided in the second wall **24** of the first fluid flow passage **20**. As shown in the cross-sectional views of FIGS. **2** and **3**, the inlet/outlet opening **68** is substantially concentrically aligned with the first communication opening **56** in the first wall **22** of the first fluid passage **20**, with the first communication opening **57** in the first wall **38** of the second fluid passage **36** and also with the first communication passage **60**, for reasons which will be explained below. Also, as shown in FIGS. **2** and **3**, the inlet/outlet opening **68** has a diameter greater than that of the first communication openings **56**, **57**.

As can be appreciated from the above discussion, heat exchanger **10** may be assembled from a plurality of plates which may be joined together by brazing. As such, significant stack-up tolerance variation may be introduced during assembly of heat exchanger **10**. The stack-up tolerance variation is the sum of a number of individual variations introduced during the manufacture, assembly and brazing of the components making up heat exchanger **10**. For example, during manufacture of the components, there will be small variations in the sizes of openings **56**, **58** and **68**; and in the locations of the openings **56**, **57**, **58**, **59** and **68** in the respective walls **22**, **38** and **24**. Because the openings **56**, **57** and **68** are formed in different components, additional variations will be introduced during assembly and brazing. Therefore, there can be expected to be variations in the concentricity of the openings **56**, **57** with each other, and with the inlet/outlet opening **68**.

An inlet/outlet fitting **70** is received in the inlet/outlet opening **68**. The inlet/outlet fitting **70** includes two flow passages for the coolant, namely an inner tubular flow passage **72** surrounded along a portion of its length by an outer annular flow passage **74**. In the illustrated embodiment, the inner tubular flow passage **72** serves as the coolant inlet flow passage and the outer annular flow passage **74** serves as the coolant outlet flow passage. The inlet/outlet fitting **70** may be formed from a metal such as aluminum or an aluminum alloy, and is shown as having an integral, one-piece construction. The one-piece construction provides precise, concentric alignment between the inner flow passage **72** and the outer flow passage **74**. In other words, the concentric orientation between the inner and outer flow passages **72**, **74** is fixed due to the one-piece construction of the inlet/outlet fitting **70**.

The inner tubular flow passage **72** is defined by an inner cylindrical tube **76** having a first end **78** located outside the heat exchanger **10** and which is adapted to seal to a fluid flow conduit, and a second end **80** located inside the heat exchanger **10**. In use, the first end **78** of the inner cylindrical tube **76** will be sealingly received inside an opening **82** in a coolant manifold **84** containing coolant galleries. A portion of the manifold is shown in FIG. **2**. As shown, the inner cylindrical tube **76** has an outer surface **86** which is provided with a resilient sealing member such as an O-ring **88** which sealingly engages a first inner bore **90** of the opening **82** in the coolant manifold **84**. The O-ring **88** is retained within a circumferential groove **89** in the outer surface **86** of the inner cylindrical tube **76**.

The outer annular flow passage **74** comprises an outer annular ring **92** having a cylindrical outer surface **94**, a first end **96** and a second end **98**. The annular ring **92** surrounds the inner cylindrical tube **76** along a portion of its length and is located between the first and second ends **78**, **80** of the inner cylindrical tube **76**, so that the ends **78**, **80** of the inner cylindrical tube **76** extend from and project past the ends **96**, **98** of the annular ring **92**.

The outer annular ring **92** has a plurality of apertures **100** extending between the first and second ends **96**, **98** of annular ring **92**. Together, the apertures **100** define the outer annular passage **74**. In the embodiment shown in the drawings, the apertures **100** extend parallel to the inner cylindrical tube **76** and the inner tubular passage **72**. As best seen in the isolated views of FIGS. **5** and **6**, the apertures may be somewhat kidney shaped in cross-section, however, it will be appreciated that the cross-sectional shape of the apertures **100** is not critical. The areas of the annular ring **92** between adjacent apertures **100** comprise webs **102** which rigidly connect the outer annular ring **92** to the inner cylindrical tube **76**, and maintain a fixed, concentric orientation of the inner cylindrical tube **76** within the annular ring **92**.

In use, the annular ring **92** of the inlet/outlet fitting **70** fits within a second inner bore **108** of the opening **82** in coolant manifold **84**, as shown in FIGS. **2** and **3**. The second inner bore **108** has a diameter greater than that of the first inner bore **90** and includes a manifold space **110** to receive the coolant from the outer annular passage **74**. The outer surface **94** of outer annular ring **92** is provided with a resilient sealing member such as an O-ring **116** which sealingly engages the second inner bore **108** of the opening **82** in the coolant manifold **84**. The O-ring **116** is retained within a circumferential groove **118** in the outer surface of annular ring **92**. The second inner bore **108** may include an inwardly-extending shoulder **112** which engages an outer chamfered edge **114** of the first end **96** of annular ring **92** to prevent over-insertion of fitting **70** into opening **82** of manifold **84**.

The opening **82** in coolant manifold **84** may be formed by machining, and can be expected to have precise dimensional tolerances. Therefore, the first and second bores **90**, **108** can be expected to have a high degree of concentricity. Thus, in order to form a reliable seal, the sealing surfaces of the inner cylindrical tube **76** and annular ring **92** of fitting **70** must also have a high degree of concentricity. The inventors have found that the one-piece, rigid construction of the inlet/outlet fitting **70** achieves concentricity of the sealing surfaces with sufficient precision to reliably form seals with the bores **90**, **108** of manifold **84**.

At least a portion of the first end **96** of outer annular ring **92** may be flat and planar, as shown in the drawings, although this is not essential to the invention.

The second end **98** (i.e. lower end in FIGS. **2** and **3**) of the outer annular ring **92** is formed with a planar outer portion, parallel to the first and second walls **22**, **24**, **38**, **40**, which provides an annular sealing surface **104** which sits on the outer surface of the second wall **24** of the first flow passage **20**, and is sealed to second wall **24**, for example by brazing or welding. The annular sealing surface **104** has an outer diameter at its outer peripheral edge which is greater than the diameter of the inlet/outlet opening **68**, such that the annular sealing surface **104** engages and is sealed to the second wall **24** in an area surrounding the inlet/outlet opening **68**. The annular sealing surface **104** is planar, and is perpendicular to both the inner cylindrical tube **76** and the outer annular ring **92**, and to their sealing surfaces in which O-rings **88** and **116** are provided. Therefore, when annular sealing surface **104** engages the second wall **24** of heat exchanger **10**, the annular sealing surface **104** sits flat on the second wall **24**, to provide and maintain vertical orientation of the inlet/outlet fitting **70** during assembly and brazing. Precise vertical alignment of fitting **70** is important to ensure a reliable seal with the manifold, and the inventors have found that the provision of the planar, annular sealing surface **104** provides this alignment, while also maintaining a reliable (brazed or welded) seal with the second wall **24** of the first flow passage **20**.

As shown in FIGS. **2** and **3**, a shoulder **106** is located at the inner peripheral edge of the annular sealing surface **104**. The shoulder **106** has a cylindrical shape and is angled at about 90 degrees relative to the annular sealing surface **104**, having a vertical orientation in the views of FIGS. **2** and **3**. The shoulder **106** and the inner peripheral edge of annular sealing surface **104** both have a diameter which is smaller than the diameter of the inlet/outlet opening **68**, and thus the shoulder **106** fits inside the inlet/outlet opening **68** and helps to locate the inlet/outlet fitting **70** relative to the inlet/outlet opening **68** during assembly.

There is also a surface **105** extending inwardly from shoulder **106** to the inner tube **76**. This surface **105** is shown as being flat and parallel to the annular sealing surface **104**, although this is not essential. In the illustrated embodiment, the height of the shoulder **106** separating surfaces **104** and **105** is at least as great as the thickness of wall **24**.

As shown in FIGS. **2** and **3**, the second end **80** of the inner cylindrical tube **76** extends through the first fluid flow passage **20**, such that the inner tubular passage **72** of the fitting **70** is in flow communication with the second fluid flow passage **36** via the first communication passage **60**. The second end **80** of the inner cylindrical tube **76** is sealed to portions of wall(s) **22** and/or **38** in which the communication openings **56**, **57** are formed, i.e. the inner peripheral surfaces of openings **56**, **57**, and/or those portions of wall(s) **22** and/or **38** immediately surrounding the openings **56**, **57**, the seal being formed by welding or brazing. In the illustrated embodiment, the first communication openings **56**, **57** in walls **22**, **38** have the same diameter, and the outer surface of tube **76** may be sealed to the inner peripheral surfaces of both openings **56** and **57**, and/or portions of wall(s) **22** and/or **38** immediately surrounding the openings **56**, **57**.

It will be appreciated that the first communication opening(s) **56** and/or **57** may optionally be formed with upstanding flanges which extend along the outer surface of tube **76** and increase the sealing area between the tube and the first communication opening(s) **56** and/or **57**. Alternatively, the second end **80** of inner cylindrical tube **76** may extend only partially through communication opening **56**, or may not extend into communication opening **56** at all, so as to avoid any "tilting" of the fitting where, for example, the communication openings **56**, **57** are misaligned with the inlet/outlet opening **68**. Tilting of the fitting **70** will cause the fitting to deviate from its vertical orientation, which may affect the seal between fitting **70** and manifold **84**. In addition, tilting of fitting **70** may also affect the seal between the annular sealing surface **104** and wall **24**.

The second end **80** of the inner cylindrical tube **76** may have a chamfered tip **81** (FIG. **3**) to ease insertion of the tube **76** in the first communication passage **60**. However, this is not necessary in all embodiments, for example in cases where there is little or no insertion of the second end **80** of inner cylindrical tube **76** into communication passage **60** or communication openings **56**, **57**. In other embodiments, the outer surface of tube may be sealed to only one of the openings **56** or **57**, with one of the other one of the openings **56** or **57** being of a slightly larger diameter so that its inner peripheral surface is spaced from the outer surface of tube **76**.

FIGS. **3**A and **3**B show alternate arrangements of the second end **80** of inner cylindrical tube **76** and openings **56**, **57**, which would be expected to help avoid angular misalignment of the fitting **70**.

For example, FIG. **3**A shows communication opening **56** of wall **22** being of larger diameter than communication opening **57** of wall **38**. In this embodiment, the second end **80** of inner cylindrical tube **76** has a smaller diameter than opening **56** but a larger diameter than opening **57**. The second end **80** is shown as extending into opening **56**. It will be appreciated that the gaps between second end **80** of tube **76** and the openings **56** and **57** will become filled with a braze or weld fillet, to provide a seal at the end **80** of tube **76**.

FIG. **3**B shows a further alternate arrangement in which the second end **80** of the inner cylindrical tube **76** has a larger diameter than the openings **56**, **57** in respective walls **22**, **38**. The openings **56**, **57** are of substantially the same diameter. In this embodiment, a braze or weld joint will be provided between the end **80** of tube **76** and the surface of wall **22** surrounding opening **56**. Again, the gap between end **80** of tube **76** and wall **22** will be sealed by a weld or braze fillet.

As mentioned above, the heat exchanger **10** will have a significant stack-up tolerance variation, while the concentric alignment of the inner tube **76** and outer annular ring **92** of the inlet/outlet fitting **70** is fixed. Therefore, in order to achieve reliable seals between the fitting **70** and the remainder of heat exchanger **10**, the difference in diameter between shoulder **106** and opening **68** must be at least as great as the amount of misalignment of openings **56**, **57** and **68** caused by the stack-up tolerance variation mentioned above. In this way, the inlet/outlet fitting **70**, with its precisely aligned inner tube **76** and annular ring **92**, can form reliable seals with the area of wall **24** surrounding opening **68**, and with the inner peripheral surface(s) of openings **56** and/or **57**, regardless of any misalignment between opening **68** and openings **56** and/or **57** caused by the stack-up tolerance variation.

As can be seen in FIGS. **2**, **3** and **7**, the apertures **100** in the outer annular ring **92** are spaced radially inwardly from the annular sealing surface **104** and the shoulder **106**, such that the apertures **100** and the resulting outer annular passage **74** are in full fluid communication with the first flow passage **20**. Thus, the coolant exits the heat exchanger **10** by flowing from the first flow passage **20** into the outer annular passage **74** of fitting **70**.

As mentioned above, the second end **80** of the inner cylindrical tube **76** and the inner tubular passage **72** of the inlet/outlet fitting **70** extend completely through the first flow passage **20** so that the liquid coolant entering the heat exchanger **10** through the inner tubular passage **72** bypasses the first flow passage **20** and flows directly into the second flow passage **36**. In order for the coolant entering heat exchanger **10** to bypass the first flow passage **20**, the inner tubular passage **72** and the inner cylindrical tube **76** are in substantially sealed flow communication with the second flow passage **36**. Thus, it can be seen that the first communication passage **60** provides direct communication between the inner tubular passage **72** of the inlet/outlet fitting **70** and the second flow passage **36**.

In use, the liquid coolant from coolant manifold **84** enters the heat exchanger **10** through the inner tubular passage **72** of inlet/outlet fitting and flows directly into the second flow passage **36**. The coolant then flows axially to the opposite end of the heat exchanger **10**, flowing from the second flow passage **36** to the first flow passage **20** through the second communication passage **62**. The coolant then flows back toward the inlet/outlet opening **68** and enters the outer annular passage **74** of the inlet/outlet fitting **70**, from where it flows back into the coolant manifold **84**. Thus, the coolant makes two passes through heat exchanger **10**. It will be appreciated that the flow through heat exchanger **10** may be reversed, such that the coolant enters heat exchanger **10** through the outer annular passage **74** and exits the heat exchanger through the inner tubular passage **72**.

As shown in FIGS. **3** and **4**, the first and second flow passages **20**, **36** may be provided with turbulence-enhancing inserts **140**, each of which may comprise a fin or a turbulizer. As used herein, the terms "fin" and "turbulizer" are intended to refer to corrugated turbulence-enhancing inserts having a plurality of axially-extending ridges or crests connected by side walls, with the ridges being rounded or flat. As defined herein, a "fin" has continuous ridges whereas a "turbulizer" has ridges which are interrupted along their length, so that axial flow through the turbulizer is tortuous. Turbulizers are sometimes referred to as offset or lanced strip fins, and example of such turbulizers are described in U.S. Pat. No. Re. 35,890 (So) and U.S. Pat. No. 6,273,183 (So et al.). The patents to So and So et al. are incorporated herein by reference in their entireties.

A heat exchanger **200** according to a second embodiment of the invention is illustrated in FIG. **8**. Many of the components of heat exchanger **200** are similar or identical to the components of heat exchanger **10** described above, and the above description of heat exchanger **10** applies to heat exchanger **200**, except as noted below.

Heat exchanger **200** differs from heat exchanger **10** in that heat exchanger **200** includes: first portion **12** comprising a first fluid flow passage **20** defined between walls **22**, **24**; a second portion **14** comprising a second fluid flow passage **36** defined between walls **38**, **40**; and third portion **16** comprising a third fluid flow passage **65** defined between walls **66**, **67** (wall **67** not shown in FIG. **8**). It will be appreciated that the heat exchanger **200** may include more than three portions, or may include only two portions **12** and **14**.

Also, the portions **12**, **14**, **16** of heat exchanger **200** are spaced apart, with a space **52** provided between the first and second portions **12**, **14**, and a space **52'** provided between the second and third portions **14**, **16**. More specifically, a first space **52** is provided between wall **22** of the first fluid flow passage **20** and wall **38** of the second fluid flow passage **36**. Similarly, a second space **52'** is provided between wall **40** of the second fluid flow passage **36** and wall **66** of the third fluid flow passage **65**.

In this embodiment, the first communication openings **56**, **57** of walls **22**, **38** are substantially concentrically aligned, with the first communication passage **60** extending across the first space **52** provided between walls **22** and **38**.

The second end **80** of the inner cylindrical tube **76** is substantially sealed to the portion of wall **22** in which the communication opening **56** is formed. For example, as shown in FIG. **8**, the second end **80** of the inner cylindrical tube **76** may extend at least partially into first communication opening **56**. However, as noted above in relation to heat exchanger **10**, the second end **80** does not necessarily extend into opening **56**. The second end **80** of tube **76** in FIG. **8** is not sealed to plate **38** and/or first communication opening **57** of plate **38**, but rather is spaced therefrom.

As mentioned above, a second space **52'** is provided between wall **40** of the second fluid flow passage **36** and wall **66** of the third fluid flow passage **65**. Therefore, the second wall **40** of the second fluid flow passage **36** may be provided with a communication opening **56'**, which may correspond in dimensions and location to communication opening **56**, and which is aligned with openings **56** and **57**.

Bridging the first space **52** is a first spacer **120** having a hollow interior, a first end **122** forming a sealed connection with the wall **22** in which opening **56** is formed, and a second end **124** forming a sealed connection with the wall **38** in which opening **57** is formed.

For example, as shown in FIG. **8**, first spacer **120** is in the form of an annular ring comprising an inner cylindrical side wall **126**, an outer cylindrical side wall **128** spaced from the inner side wall **126**, and a bridging portion **130** extending between and connecting the side walls **126**, **128** together. In the embodiments shown in the drawings, the side walls **126**, **128** and the bridging portion **130** have a U-shaped appearance in cross-section. The second end **124** of spacer **120** may have a shoulder **125** which permits the spacer **120** to seat inside the first communication opening **57** in the first wall **38** of the second fluid flow passage **36**, thereby locating the spacer **120** relative to the communication opening **57**. The planar surface of spacer **120** surrounding the shoulder **125** forms an annular sealing surface **64** at which the spacer **120** is sealingly connected to the first wall **38** of second fluid flow passage **36**, in an area surrounding the first communication opening **57**, for example by welding or brazing. As with the shoulder **106** of the inlet/outlet fitting **70**, the shoulder **125** of the spacer **120** may have a diameter which is smaller than the diameter of first communication opening **57** by an amount sufficient to permit proper alignment of the spacer relative to openings **56**, **57** notwithstanding any stack-up tolerance variation.

In an embodiment, the side walls **126**, **128** and bridging portion **130** may be of unitary construction, and may be comprised of aluminum or an aluminum alloy.

A resilient sealing member in the form of a sealing ring **132** is received inside the spacer **120**, and is located in the annular space between the inner and outer side walls **126**, **128**. The resilient sealing ring **132** provides a resilient seal between the first end **122** of spacer **120** and the wall **22** of the first flow passage **20**. In particular, the resilient seal is formed between the first end **122** of the spacer **120** and the adjacent first portion **12** of heat exchanger **10**. In the illustrated embodiment, the surface of plate **22** facing the spacer **120** is provided with an annular groove **134** surrounding the first communication opening **56** in plate **22**. The annular groove is formed within the thickness of wall **22**.

The resilient sealing member **132** has an annular, generally cylindrical shape, with a first end received inside the annular groove **134** of wall **22** and a second end received inside the spacer **120** and in engagement with the bridging portion **130**. In the embodiment shown in FIG. **8**, the resilient sealing member **132** has a rectangular cross-section.

As can be seen in FIG. **8**, the resilient sealing member **132** may have a thickness (measured in radial direction) which is less than the distance between the inner and outer side walls **126**, **128** of spacer **120**. This permits some lateral adjustment of the first and second portions **12**, **14** of heat exchanger **10** relative to one another, so as to avoid misalignment caused by the stack-up tolerance variation.

The heat exchanger **200** will include an opposite end which is remote from the inlet/outlet fitting **70**, corresponding to the portion of heat exchanger **10** shown in FIG. **4**. The first, second and third portions **12**, **14**, **16** may also be spaced apart at this end of heat exchanger **10**, and spacers **120** may also be provided at this end of heat exchanger **200** to provide sealed connections between portions **12**, **14**, **16** in the same manner as discussed above in relation to the fitting end of the heat exchanger **200**.

As shown in FIG. **8**, the first and second flow passages **20**, **36** may be provided with turbulence-enhancing inserts **140**, each of which may comprise a fin or a turbulizer. In addition, turbulence-enhancing inserts can be provided in the space **52** between the heat exchanger portions **12**, **14**.

As mentioned above, a second space **52'** is provided between portions **14** and **16** of heat exchanger **200**, more specifically between wall **40** of the second fluid flow passage **36** and wall **66** of the third fluid flow passage **65**. A spacer **120'** and a resilient member **132'** are provided in this space **52'**. The spacer **120'** and resilient member **132'** may be identical to spacer **120** and resilient member **132** described above, however, FIG. **8** illustrates some minor variations which may be incorporated into the spacer **120'** and seal **132'**.

In this regard, the resilient sealing member **132'** has a cross-sectional shape which differs from that of resilient sealing member **132**. The resilient sealing member **132'** has an outer rib **136** and an inner rib **138** which reduce the size of the gap between the resilient sealing member **132'** and the side walls **126'**, **128'** of spacer **120'**. The ribs **136**, **138** provide the resilient sealing member **132'** with an approximate cross or t-shape, and reduce the potential for lateral misalignment. The inventors have found that the use of resilient sealing member **132'** having this profile provides accurate alignment of the second and third portions **14**, **16** of heat exchanger **200**, while avoiding excessive compressive forces.

Another variation illustrated in FIG. **8** relates to the annular groove in which the first end of the resilient sealing member **132'** is received. As shown, an annular rib **142** is provided in the area of wall **40** surrounding communication opening **56'**, and protrudes into the second fluid flow passage **36**. The rib **142** may be formed by stamping the wall **40**. An annular groove **134'** is provided in the underside of annular rib **142**, the groove **134'** receiving the first end of the resilient sealing member **132'**.

Although FIG. **8** shows a gap between the first end **122** of spacer **120** and the wall **22** of the first portion **12** of heat exchanger **200**, this is not necessarily the case. Rather, the heat exchanger **200** may be under sufficient compression that the first end **122** of spacer **120** is in contact with wall **22**, and thus acts as a “hard stop” to prevent over compression of the resilient member **132**.

Although the invention has been described in connection with certain embodiments, it is not restricted thereto. Rather, the invention includes all embodiments which may fall within the scope of the following claims.

What is claimed is:

1. A heat exchanger comprising:

at least a first enclosed fluid flow passage and a second enclosed fluid flow passage, wherein each of the fluid flow passages is defined between a first wall and a second wall;

first and second communication openings provided in the first wall of each of the first and second flow passages, wherein the first communication opening of the first flow passage aligns with the first communication opening of the second flow passage and the second communication opening of the first flow passage aligns with the second communication opening of the second flow passage;

an inlet/outlet opening provided in the second wall of the first flow passage, wherein the inlet/outlet opening is aligned with the first communication opening in the first wall of the first flow passage;

an inlet/outlet fitting received in the inlet/outlet opening, wherein the inlet/outlet fitting has an inner tubular passage surrounded by an outer annular passage, wherein the inner tubular passage is defined by an inner cylindrical tube having a first end and a second end, wherein the inlet/outlet fitting further comprises an outer annular ring having a first end and a second end, wherein the outer annular ring surrounds the inner cylindrical tube and is connected thereto, and wherein the outer annular passage is defined between the inner cylindrical tube and the outer annular ring;

wherein the second end of the outer annular ring has a planar sealing surface surrounding the outer annular passage, and wherein the planar sealing surface of the outer annular ring is sealingly connected to an area of the second wall of the first flow passage surrounding the inlet/outlet opening, such that the first flow passage is in fluid flow communication with the outer annular passage of the inlet/outlet fitting;

wherein the second end of the inner cylindrical tube extends through the first flow passage and is in sealed fluid flow communication with the second flow passage, such that the second flow passage is in fluid flow communication with the inner tubular passage of the inlet/outlet fitting;

wherein the first and second flow passages are defined by respective first and second plate pairs, each of the plate pairs comprising a pair of plates sealed together at their edges, and wherein the first plate includes the first wall and the second plate includes the second wall, and wherein the inlet/outlet opening is substantially concentrically aligned with the first communication openings in each of the first and second flow passages;

wherein the planar sealing surface of the outer annular ring has an annular shape, with an outer peripheral edge and an inner peripheral edge, wherein a diameter of the planar sealing surface at the outer peripheral edge is greater than a diameter of the inlet/outlet opening, and wherein a diameter of the planar sealing surface at the inner peripheral edge is less than the diameter of the inlet/outlet opening;

wherein the second end of the outer annular ring comprises a shoulder located at the inner peripheral edge of the planar sealing surface and outwardly from the outer annular passage, wherein the shoulder has a diameter which is smaller than the diameter of the inlet/outlet opening, and is received inside the inlet/outlet opening; and

wherein the diameter of the shoulder differs from the diameter of the inlet/outlet opening by an amount which is at least as great as a stack-up tolerance variation of the heat exchanger.

2. The heat exchanger of claim **1**, wherein the first end of the inner cylindrical tube extends beyond the first end of the outer annular ring and has an outer surface provided with a first resilient sealing member for sealing the first end of the inner cylindrical tube within a first inner bore of a fluid opening; and

wherein the outer annular ring has a cylindrical outer surface provided with a second resilient sealing member for sealing the cylindrical outer surface of the annular ring within a second inner bore of said fluid opening, wherein the first inner bore and the second inner bore are concentric with one another.

3. The heat exchanger of claim **2**, wherein the first resilient sealing member and the second resilient sealing member each comprise an O-ring.

4. The heat exchanger of claim 1, wherein the outer annular ring is integrally formed with the inner cylindrical tube, and wherein the outer annular ring is rigidly connected to the inner cylindrical tube through a plurality of webs, such that the outer annular ring is concentric with the inner cylindrical tube.

5. The heat exchanger of claim 1, wherein the second end of the inner cylindrical tube has an outer cylindrical surface having a diameter which is less than a diameter of the first communication opening in the first wall of the first flow passage, and wherein the outer cylindrical surface of the inner cylindrical tube is sealed to the first wall of the first flow passage.

6. The heat exchanger of claim 5, wherein the outer cylindrical surface of the inner cylindrical tube is sealed to an inner peripheral surface of the first communication opening of the first flow passage.

7. The heat exchanger of claim 5, wherein the outer cylindrical surface of the inner cylindrical tube is sealed to the first wall of the first flow passage by brazing or welding.

8. The heat exchanger of claim 1, wherein the first wall of the first flow passage is in engagement with the first wall of the second flow passage, and wherein the first communication openings of the first and second flow passages are in substantial concentric alignment with one another.

9. The heat exchanger of claim 8, wherein the second end of the inner cylindrical tube extends at least partially through the first communication opening in the first wall of the second flow passage.

10. The heat exchanger of claim 9, wherein the second end of the inner cylindrical tube is sealed to the first wall of the second flow passage within the first communication opening of the second flow passage.

11. The heat exchanger of claim 1, wherein a space is provided between the first wall of the first flow passage and the first wall of the second flow passage.

12. The heat exchanger of claim 11, wherein a spacer is provided in the space between the first wall of the first flow passage and the first wall of the second flow passage, wherein the spacer comprises:

a hollow interior;

a first end forming a sealed connection with the first wall of the first flow passage in an area surrounding the first communication opening of the first flow passage; and

a second end forming a sealed connection with the first wall of the second flow passage in an area surrounding the first communication opening of the second flow passage.

13. The heat exchanger of claim 12, wherein the spacer comprises an annular ring having an inner cylindrical side wall, an outer cylindrical side wall spaced from the inner cylindrical side wall, and a bridging portion extending between and connecting the side walls together, wherein the inner cylindrical side wall, the outer cylindrical side wall and the bridging portion together define the hollow interior of the spacer.

14. The heat exchanger of claim 13, wherein the inner and outer cylindrical side walls and the bridging portion of the spacer have a U-shaped appearance in cross-section, and wherein the second end of the spacer includes a shoulder which is received inside the first communication opening in the first wall of the second fluid flow passage.

15. The heat exchanger of claim 12, wherein the spacer further comprises a resilient sealing member in the form of a sealing ring received inside the hollow interior.

16. The heat exchanger of claim 15, wherein the first wall of the first flow passage has an annular groove surrounding the first communication opening formed therein, and wherein the resilient sealing member has a first end received inside the annular groove and a second end received inside the hollow interior of the spacer, in engagement with the bridging portion.

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